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COMBUSTION OF GAS SUSPENSION OF METAL POWDERS AND EFFECT OF PARTICLE SIZE ON EXPLOSIBILITY PARAMETERS

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

FOLLOWING ARE THE CORRESPONDING RUSSIAN AND ENGLISH DESIGNATIONS OF THE TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}
rot	curl
lg	log

GREEK ALPHABET

Alpha	Α	α	∝		Nu	Ν	ν	
Beta	Β	β			Xi	Ξ	ξ	
Gamma	Γ	γ			Omicron	Ο	ο	
Delta	Δ	δ			Pi	Π	π	
Epsilon	Ε	ε	ϵ		Rho	Ρ	ρ	ϱ
Zeta	Ζ	ζ			Sigma	Σ	σ	ς
Eta	Η	η			Tau	Τ	τ	
Theta	Θ	θ	ϑ		Upsilon	Τ	υ	
Iota	Ι	ι			Phi	Φ	φ	ϕ
Kappa	Κ	ϰ	κ	ϰ	Chi	Χ	χ	
Lambda	Λ	λ			Psi	Ψ	ψ	
Mu	Μ	μ			Omega	Ω	ω	

COMBUSTION OF GAS SUSPENSION OF METAL POWDERS AND EFFECT OF PARTICLE SIZE ON EXPLOSIBILITY PARAMETERS

V. V. Nedin, O. D. Neykov,
A. G. Alekseyev, G. I. Vasil'yeva,
and Ye. S. Kostina

The processes in which metal powders are obtained and used involves the formation of gas suspensions which ignite under certain conditions. This endangers human life and can result in considerable material loss. The original data used in developing the technology of explosion prevention in the production and use of powders are the main characteristics of ignitability and explosibility of the gas suspension.

In the Institute of the Problems of Material Science of the AS USSR methods have been developed and a complex of equipment created to study the ignitability and explosibility characteristics of dispersed metal powders.[1] These devices make it possible to obtain a gas suspension with a sufficiently uniform concentration and to monitor the concentration in time and space and register thermal explosion parameters. The minimal ignition

[1]V. V. Nedrin et al. Explosion Prevention for Metal Powders. Kiev, "Naukova dumka", 1971.

temperature, explosion pressure, the rate of its increase, and the lower and upper concentration levels of explosibility (lcl [нкп] and ucl [вкп]) are determined. The concentration limits are determined by establishing the moment of admission and the concentration of particles in the initiator zone of the gas suspension which accompanies it.

In the present work we examine the results of studies on the above characteristics for pyrophore and explosive powders of reduced iron and electrolytic titanium.

Table 1 shows the lower concentration level [lcl], maximal pressure Δp, and the rate of increase in explosion pressure V_p of iron commodity powders of brand PZhM and fractions smaller than 50 μm separated from them.

The study showed that maximal explosion pressure in a gas suspension of powders smaller than 50 μm does not exceed 2.5 kgf/cm^2, while the maximal rate of increase in explosion pressure reaches 30 kgf/cm^2·s. For commodity powders explosion pressure and the rate of increase in explosion pressure do not exceed 1.8 kgf/cm^2 and 10 kgf/cm·s, respectively. In the range of concentrations close to the lcl we observe a significant scatter in explosion pressure. However, the obtained maximal values indicate that as the concentration is increased up to 2-3 g/l explosion pressure increases intensively, while further increasing the concentration results only in an insignificant increase in explosion pressure.

The explosibility characteristics depend on the concentration of iron, carbon, and oxygen in the powder. For example, for powders of brand PZhM of the Sulinskiy Metallurgical Plant with the same dispersion content and iron concentrations of 98 and 97.5% the lcl is 110 and 287 g/m^3, respectively.

The explosibility parameters of fractions with particles

Table 1

Powder		Composition, % - Fe	C	S	P	Mn	Si	O_2	Particle content, wt. % larger than 280 µm	280–160 мк	160–100 мк	100–71 мк	71–56 мк	56–50 мк	finer than 50 µm	Explosibility parameters lcl, g/l	$\Delta P_{макс}$, кГ/см²	$V_{p\ макс}$ кГ/см²·сек.
Vroyarskiy Powder Metallurgical Plant	PZhM	98,1	0,09	0,02	0,01	0,33	0,1	1,0	0,3	12,5	36,2	27,9	17,3	1,8	4,0	0,875	0,1	1,0
	PZhM	97,5	0,22	0,02	0,01	0,23	0,09	H	0	7,6	23,0	49		8,0	12,4	0,13	0,6	3,0
	PZh finer than 50 µm	97,5	0,22	0,03	0,01	0,23	0,09	H	0	0	0	0		0	100	0,066	1,7	18,0
Sulinskiy Metallurgical Plant	PZhM	97,5	0,11	0,01	0,01	0,40	0,25	1,5	0	1,6	23,2	25,4	12,6	11,8	25,4	0,287	1,3	13,2
	PZhM	98,0	0,12	0,01	0,08	0,33	0,25	H	0	2,6	23,3	37,6		12,4	24,1	0,110	0,9	18,0
	PZh finer than 50 µm	97,5	0,12	0,01	0,01	0,40	0,25	1,7	0	0	0	0	0	0	100	0,114	2,3	16,5
Novo-Tul'skiy Metallurgical Plant	PZhM	98,1	0,07	0,02	0,03	0,30	0,19	1,0	0	0,6	17,6	32,8	12,8	11,3	24,9	0,35	1,45	13,0
	PZh finer than 50 µm	98.1	0,07	0,02	0,03	0,30	0,19	1,0	0	0	0	0	0	0	100	0,146	2,4	18,0
Dneprovskiy Aluminum Plant	PZhM	98,6	0,08	0,01	0.01	0,31	0,08	0,4	0	16,6	44,5	23,0	5,9	1,9	8,1	0,46	0,75	2,0
	PZhM	97,1	0,05	0,02	0,02	0,30	0,16	1,5	3,6	0,6	24,9	27,5	9,3	5,4	23,7	0,20	1,8	10,0
	PZh finer than 50 µm	98,5	0,06	0,02	0,02	0,35	0,18	0,9	0	0	0	0	0	0	100	[illegible]	2,5	30,0

Note. N - not determined.
Abbreviation: кГ/см^2=kgf/cm^2; сек=s; мк=µm.

smaller than 40 μm isolated from commodity PZhM brand powder of the Dnepr' Aluminum Plant, in which the concentration of oxygen varies from 0.2 to 2.1%, showed that when the concentration of oxygen is increased about 1.2% the activity of the powders is significantly reduced. Figure 1 describes the effect of the degree of oxidizability of the powders on the lcl n. As the result of studies on artificially oxidized powder it was established that powders containing 5% oxygen do not explode.

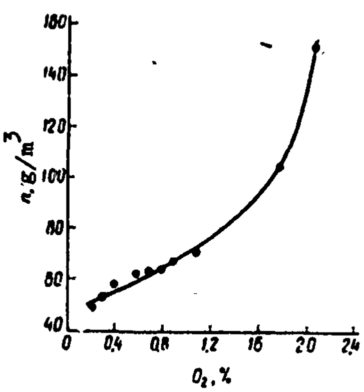

Figure 1. Effect of oxygen concentration in iron powders on lower concentration limits of explosibility.

The degree of dispersion of the powders has a substantial effect on the explosibility parameters: for a more active powder with particles of less than 50 μm the lcl is 66 g/m^3, while for PZhM powders of the Vrovarskiy Powder Metallurgical Plant, containing only 4% of fractions smaller than 50 μm, the lcl is 875 g/m^3, and still larger PZhS powders did not explode at all.

Powders of electrolytic titanium have a greater tendency to explode as compared to powders of reduced iron: they have lower lcl values and higher developed pressure levels.

The concentration of titanium in all studied powders was above 99%, oxygen - 0.4%. Polydispersed powders were studied (commodity powders smaller than 560 μm and fractions smaller than 40 μm) along with various powder fractions obtained by sifting through a sieve with mesh openings up to 15 μm.

The polydispersed powder had the following dispersion composition: 160-560 μm - 3.85%; 100-160 μm - 6.4%; 80-100 μm - 2.36%; 71-80 μm - 18%; 50-71 μm - 36%; 40-50 μm - 13%; 30-40 μm - 19%; 15-30 μm - 3.99%; smaller than 15 μm - 1.4%.

Table 2 presents the results of a study on the effect of of powder dispersion on the lcl and explosion pressure at different powder concentrations. As we see in the table, as the particle size changes from 7.5 to 53 µm the lcl changes slightly, but rises rapidly with a further increase in particle diameter. Explosion pressure at different powder concentrations declines as particle diameter increases. Maximal explosion pressure is observed at concentrations of 1000-1200 g/m³.

Table 2

Powder fraction of titanium, µm	d_{cp}, µm	lcl, g/m³	Explosion pressure (kgf/cm²) for concentration, g/cm³						
			100	200	400	600	800	1000	1200
Polydispersed	63,5	64	1,0	1,5	2,5	3,2	3,5	3,75	3,75
smaller than 40	29,4	40	1,5	2,3	3,0	3,5	3,75	3,9	3,9
— 15	7,5	34	1,35	2,1	3,0	3,6	4,0	4,2	4,0
+15— 30	22,5	36	1,35	2,0	2,8	3,5	3,8	3,9	3,8
+30— 40	35,0	38	1,2	1,8	2,6	3,2	3,4	3,6	3,6
+40— 50	45,0	40	1,15	1,7	2,4	2,75	3,2	3,4	3,6
+50— 56	53,0	36	1,1	1,75	2,6	3,25	3,5	3,7	3,7
+56— 63	59,5	56	1,1	1,7	2,6	3,25	3,4	3,5	3,5
+56— 71	63,5	58	1,0	1,4	2,1	2,5	2,6	3,0	3,0
+71— 80	75,5	80	0,5	1,2	1,8	2,5	2,7	3,2	3,5
+80—100	90,0	90	0,3	0,9	1,7	2,2	2,6	2,9	3,2
+100—160	130,0	194	0,0	0,2	0,3	0,5	1,2	1,5	1,8
+160—250	205,0	Not exploded							
Polydispersed	63,5	20	1,0	1,5	2,5	3,4	3,5	3,75	3,8

Figure 2 shows the maximal explosion temperature, rate of pressure increase, minimal ignition temperature[1] and lcl as a function of particle size.

Air suspensions with a fraction of 160-250 µm were not exploded by a powerful ignitor of the pyrophore mixture. When particle

[1]A. P. Kuzub and A. F. Shapoval participated in determining minimal ignition temperature.

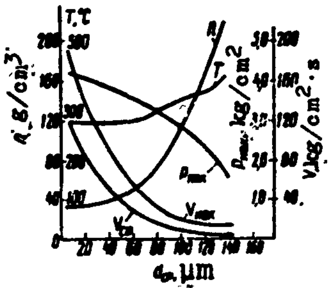

Figure 2. Effect of particle size of titanium powders on main explosibility characteristics.

size is reduced explosion pressure and the rate of pressure increase rise up to the smallest particles. The minimal ignition temperature, just as the lcl, remains practically constant for particles smaller than 50-60 μm. For larger particles the ignition temperature and the lcl increase, respectively.

As particle diameter increases so does the explosion-proof concentration of oxygen in the inert medium. Thus, for particles with diameters of 7.5, 35, 53, and 63.5 μm dispersed in gas the explosion-resistant concentration of oxygen in the argon is equal to 1.7, 1.8, 3.0, 4.1%, respectively.

The lcl of the explosibility of titanium is influenced by the initial concentration of oxygen in the powder. Increasing the concentration of oxygen from 0.12 to 0.194% increases the lcl of powder smaller than 71 μm from 44 to 60 g/m^3. Polydispersed powder (d_{cp}=63.5 μm) containing 0.1% oxygen had an lcl of 20 g/m^3.